5 MINERνA Software

5.1 Overview

Software and computing resources are an integral part of the MINERνA project. These resources will be used to accommodate two primary tasks for MINERνA :

1. Data storage after acquisition under experimental running conditions

2. Data analysis and numerical modeling.

Detailed numerical modeling is necessary for the experimenters on MINERνA to gain the most complete understanding of the detector as possible. Data event selection and reconstruction goes together with the detailed detector model to both improve understanding of the detector response and analyze physics production data. Physical computing resources, including:

1. Raw and processed data storage

2. Detector model output and analysis storage

3. Raw and modeling data processing computer processor usage

are needed to complete analysis of MINERνA physics data. The MINERνA project has developed a technical design for obtaining these software and computing resources.

Data processing needs for the MINERνA experiment are divided into two main categories:

1. Generation and analysis of detector modeling events.

2. Event selection and reconstruction of real physics data from the physical MINERνA detector.

Certainly, it can be argued that these are not exclusive needs. For example the reconstruction packages used in the reconstruction of real physics events are, or at least may be, the same as those used for certain analysis of real physics data. Software which must be developed or implemented for this experiment includes but is not limited to:

1. The generation of neutrino events, including models of nuclear effects on neutrino-nucleon interactions.

2. Accurate descriptions of the MINERνA detector during design and after construction (finish design).

3. A method of relaying accurate commissioning and calibration information to both simulation software and reconstruction software for real physics data.

4. Reconstruction and event selection routines suitable for use with both simulated and real physics data.

5. Analysis and visualization software for interpreting and displaying the results.

These needs can be met using a combination of pre-existing software and new software development or implementation.

The use of pre-existing software packages, particularly those which have been designed with physics analysis as their primary function, will help reduce the amount of time required to meet the software development needs of the MINERνA project. For example, many packages already exist which can be used for data analysis and visualization. These packages are readily available at little or no cost to the experiment, or individual collaborator's institutions. The software development plan for simulation, reconstruction, and analysis requires the best-use of object-oriented programming techniques. The use of object-oriented programming techniques will allow MINERνA experimenters to use modern, well-supported, software tools to their best advantage, as well as making the use of varying analysis and reconstruction routines reasonably seamless. As of the writing of this document the following software packages were under review (but need not be limited to):

- GAUDI, a framework package, and its support packages.
- Geant4, a simulation package.
- ROOT, a data visulaization and analysis package.

Meeting these software and physical computing needs is a collaborative effort. The members of the MINERνA collaboration are providing individuals to organize, develop, and train the full collaboration in the proper use of the software under construction. Physical computing resources will need to be provided from various sources, not the least of which is the Fermi Lab Computing Division. From the Laboratory, the MINERνA project will require mass-storage of raw, reconstructed, and simulated data. Centralized access to developed software and data will also be a necessity. These, among other needs from the Fermi Lab Computing Division will be addresses in a formal Memorandum of Understanding between the project and the Computing Division. Clearly, meeting the computing needs of the MINERνA project is a collaborative effort.

5.2 Beam Simulation and Neutrino Event Generation

In order to produce a useful numerical model of the MINERνA detector two inputs are required:

1. A high quality model for the neutrino beam energy spectrum.
2. A generator of neutrino-interaction events.

At this time, the members of the MINERνA collaboration plan to neither manufacture nor maintain the external software which provides these necessary components of detector simulation. This decision was made pursuant to the availability of readily available software providing both beam energy spectra for the NuMI beam and not less than two reliable neutrino-event generators.

The neutrino beam energy spectra are provided to the MINERνA project from the NuMI working group of the Fermilab Neutrino Departmeent. Neutrino energy spectra are produced using a numerical modeling package called GNuMI. This model was expressly developed for the NuMI beam line at Fermi Lab, and can provide profiles for various arrangements of the tuning horns along the beam line. Please see reference 1 for more information about how GNuMI models neutrino beam energy spectra. These spectra are delivered, and used by the MINERνA collaboration as text vectors.

Neutrino-interaction events are, in general, generated using one of two readily available neutrino event generators, NEUGEN and NUANCE. Both of these event generators can be used to simulate the four classifications of interactions of interest to the MINERνA project:

1. Quasi-elastic neutrino scattering.

2. Resonance production from neutrino scattering.

3. Deeply-Inelastic neutrino scattering.

4. Coherent production from neutrino scattering.

These event generators have been designed to incorporate nuclear effects in neutrino-interactions by incorporating the best available theoretical models and data. Appropriate accommodation will be made for use output of these event generators as input to numerical simulation of the detector. The MINERνA collaboration has members who are instrumental in the design and maintenance of these generators through the respective collaborations designing them. Further information containing the methods used in NUANCE and NEUGEN can be found in references 2 and 3.

5.3 Code Management

Maintaining the quality and accessibility of computer code is imperative for the MINERνA collaboration. Proper code management requires two primary objectives:

1. Proper version maintenance and propagation.

2. Enforcement of best-practices in program design and documentation as determined by the members of the MINERνA collaboration.

Laboratory infrastructure and MINERνA collaboration effort are necessary to assist in attaining these objectives.

A Concurrent Versions System (CVS) server has been established at Fermi Lab for use by the MINERνA collaboration for storing and propagating necessary tools and other information. This server, setup by the Computing Division and maintained by the Collaboration, was negotiated as part of the MINERνA Memorandum of Understanding with the Fermi Lab Computing Division. Through CVS multiple versions of the same software can be made available as corrections are made and features are added without loss of the previous versions. This server is availability only to members of the MINERνA collaboration and is not publicly accessible.

The enforcement of best-practices in conforming to the object-oriented nature of the simulation and analysis software development plan is the job of a software librarian. This individual is identified internally by the MINERνA collaboration. The software librarian is responsible for assisting those working on software projects in understanding the best-practices established by the collaboration, ensuring that tests for quality assurance and consistency are performed by developers before releasing new or corrected software for collaboration use, and insisting upon the proper documentation of software projects is produced such that all collaboration members can make use of simulation and analysis software.

5.4 Data Processing (Handling), CPU, and Storage

Data processing, CPU, and data storage requrirements are detailed in the Memorandum of Understanding (MOU) between the Computing Division at Fermi Lab and the "project". These requirements are likely to change as the simulation and reconstruction software is better understood.

References

1. NEED A REFERENCE!
2. D. Casper, "The `nuance` Neutrino Physics Simulation, and the Future", $http://nuint.ps.uci.edu/nuance/fil$
3. H. Gallagher, Nucl. Phys. B Proc. Suppl., **112** 188 (2002).